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(71) Applicant
British Gas Plc

(Incorporated in the United Kingdom)

152 Grosvenor Road, London, SW1V 3JL, United Kingdom

(72) Inventor
Phillip Graham

(74) Agent and/or Address for Service
Robert J Cummings
c/o British Gas Corporation, 326 High Holborn, London, W1V 7PT, United Kingdom

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(54) Apparatus for monitoring or measuring differential fluid pressure

(57) The apparatus monitors or measures differential pressures which arise for example across orifice plates or other components in pipes conveying natural gas or other compressible fluids, particularly in orifice flow meter applications. The effects on accuracy of spurious perturbations in the transducer lead lines, caused by pressure perturbations in the pipe 10, are eliminated or reduced by using two differential transducers 12, 14 communicating via acoustically equivalent paths 22, 24 with a common location at which a back-pressure P3 is sensed. Conveniently, the pressure P3 is sensed immediately downstream of an orifice plate 30, the transducers sensing pressures P1 and P2 at opposite sides of the plate 30. Additional but optional precaution against spurious perturbations in the lead lines is provided by damper material 36 and a reactive and/or dissipative filter 42. Alternatively, the transducer diaphragms 16 are mounted in the wall of the pipe 10; the material 36 and the filter 42 can be omitted. The transducers 12, 14 need not be matched.

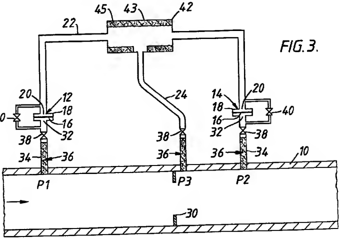

FIG. 3.

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FIG. 1.

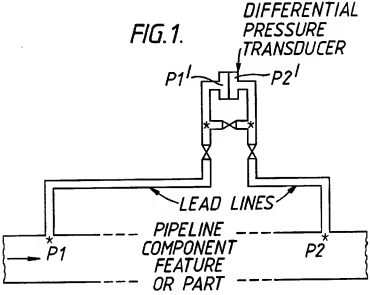
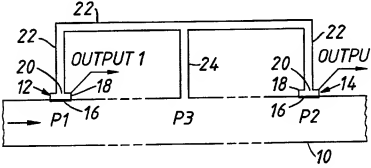
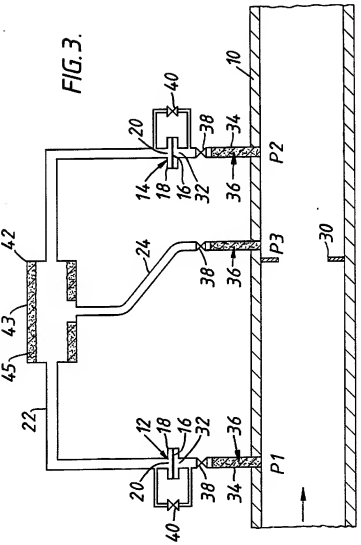

DIFFERENTIAL
PRESSURE
TRANSDUCER
P1'
P2'
LEAD LINES
PIPELINE
COMPONENT
FEATURE
OR PART
P1
P2

FIG. 2.


22
22
22
OUTPUT 1
OUTPUT 2
24
20
20
12
18
18
14
16
16
P1
P3
P2
10



10
40
20
38
34
14
18
16
32
36
P2
42
24
38
36
P3
30
43
45
22
12
18
16
32
36
20
38
34
P1
40

FIG.3.

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APPARATUS FOR MONITORING OR MEASURING DIFFERENTIAL FLUID PRESSURE

The invention relates to apparatus for monitoring or measuring difference between pressures in compressible fluid particularly, though not exclusively, in natural gas distribution systems in connection with gas flow measurement.

It is common practice to locate a differential pressure transducer remotely from the positions where fluid pressure is sensed. Errors occur in the signal from the transducer caused by pressure perturbations in the fluid being sensed e.g. in the gas flow in a pipe. The pressure perturbations may cause resonant perturbations in the gas in the lead lines connecting the transducer to the pipe.

The object of the invention is to provide apparatus in which such errors are eliminated or greatly minimised.

Apparatus for monitoring or measuring difference between pressures in compressible fluid at first and second locations, according to the invention, comprises first and second differential transducers having respective transducer elements positioned at or adjacent the first and second locations, respectively, respective first sides of the elements communicating with the respective locations and respective second sides of the elements communicating with a common third location through respective acoustically equivalent paths.

In one form of apparatus, for example, the transducer elements are mounted in respective openings in wall portions comprising the respective first and second locations.

Alternatively, the transducers have respective second pressure ports through which the respective first sides of the transducer elements communicate with the respective first and second locations.

Preferably, the first pressure ports are connected by means defining a fluid path, which has a branch path leading to the third location.

In one form of apparatus, for example, the path includes an acoustic filter or damper at the junction with the branch path.

Embodiments of the invention will now be described by way of example with reference to the accompanying drawings, in which:

Figure 1 is a schematic diagram showing a known arrangement of a differential pressure transducer responsive to pressures upstream and downstream of a straight part of a pipe or upstream and downstream of a component of the pipe such as an orifice plate, for example;

Figure 2 is a schematic diagram showing a first embodiment of apparatus according to the invention;

Figure 3 is a schematic diagram showing a second embodiment of apparatus, in greater detail, according to the invention.

Figure 1 shows a typical known arrangement of a differential pressure transducer, which is positioned remotely from a component, such as an orifice plate, for example, in a pipe conveying compressible fluid. For example, the pipe conveys natural gas in a distribution system. The transducer is connected to the pipe by two small-bore lengths of tubing forming lead lines, which extend from the wall of the pipe adjacent the two locations at which the pressures in the pipe are required to be sensed. The direction of flow through the pipe is as indicated by the arrow.

So long as flow through the pipe is steady with only relatively small perturbations, there is effectively no flow in the lead lines and the time-averaged values $\overline{P1} = \overline{P1'}$ and $\overline{P2} = \overline{P2'}$. The differential pressure across the tranducer element, such as a diaphragm for example, is the same as the differential pressure across the orifice plate or other component, feature or part. When relatively greater perturbations occur in the pipe, significant perturbations may arise in the lead lines. Depending on the frequencies present in the pipe perturbations, the gas or other fluid in the lead lines may be forced to flow in an oscillatory mode at acoustically resonant frequency, which may cause substantial flow perturbations to build up in the lead lines.

At changes of cross-section in the lead lines the relationship between pressure difference and flow is directionally non-linear i.e. fluid is more easily perturbed in one sense compared with the other. As a consequence, differential pressures may occur in the lead lines, so that

$\overline{P1} \neq \overline{P1'}$ and $\overline{P2} \neq \overline{P2'}$. Generally, the differential pressure $\overline{P1} - \overline{P2} \neq \overline{P1'} - \overline{P2'}$ i.e. errors have been caused in the system. Such errors are often sensitive to small changes in operating or environmental conditions. Moreover, such errors are difficult to quantify theorectically and may appear seemingly at random.

In Figure 1 the asterisks * indicate positions at which non-linearity errors may occur.

Figure 2 shows one form of apparatus, embodying the invention, by which such errors can be eliminated or greatly minimised. The difference between the pressures $\overline{P1}$ at a first location in a pipe 10 and $\overline{P2}$ at a second location is required to be monitored or measured. For example, the locations may be respectively upstream and downstream of a component (not shown) such as an orifice plate in the pipe. The apparatus may typically be used for monitoring or measuring the flow of a compressible fluid such as natural gas, for example, through the pipe 10.

The required difference between the pressures at the two locations is the difference between the outputs of the two transducers divided by the transducer sensitivity (for identical transducers). The difference so found is converted to a value of flowrate using well-known priciples.

Two differential pressure transducers 12, 14 are shown in Figure 2. Each has an element in the form of a flexible diaphragm 16 mounted in a housing 18. Each housing 18 is in turn mounted in a respective opening in the wall of the pipe 10. The respective first, lower sides of the elements 16 are at the locations at which the pressures P1, P2 are to be sensed. Each housing 18 has a respective pressure port 20 and the pressure ports are connected to each other by a fluid path in the form of a line 22 formed of small-bore tubing. The path has a branch line 24, also of small-bore tubing, leading to a third location within the pipe 10. The branch 24 opens at the pipe wall so that a third pressure P3 is sensed at a third location intermediate the locations at which P1 and P2 are sensed. For example, the third location may be immediately downstream of an orifice plate, as in Figure 3.

The transducers each produce a signal output corresponding to the difference between the pressure at the respective location at which P1 or P2 is sensed and the pressure within the housing 18, is a reference pressure and which may be called a back-pressure. The back-presures in the housings 18 are equal because the parts of the line 22 on either side of the branch line 24 are effectively exactly identical. The respective second, upper sides of the diaphragms 16 therefore communicate with the P3 location through acoustically equivalent paths formed by those parts of the line 22 and through the common branch line 24. Non-linear effects in the lines 22, 24 generally mean that the back-pressure is not equal to P3, but that is immaterial.

For identical transducers, the differential pressure $\overline{P1} - \overline{P2}$ is represented by the difference between the outputs of the transducer 12 and the transducer 14, divided by the transducer sensitivity.

A further advantage is that the transducers need not be matched nor maintain a precisely matched status. The effect of relative drift of the transducer characteristics is of the same order as the effect of sensitivity drift of a single transducer in a system of the kind shown in Figure 1. Errors in the system shown in Figure 2 are to some extent dependent on the value of the back-pressure, which may vary depending upon the amplitude of perturbations in the pressure P3. A further advantage is that the location at which P3 is sensed can readily be chosen to be at a "quiet" position in the pipe i.e. a location where perturbations are minimal.

Figure 3 shows a modified form of apparatus, in which parts corresponding to those shown in Figure 2 are given the same reference number. The P1 and P2 locations are shown, respectively, at the upstream and downstream sides of an orifice plate 30. The P3 location is downsteam of, and adjacent, the plate 30.

The transducer elements, the diaphragms 16 are mounted within repsective housings 18, which have lower pressure ports 32 connected by relatively short lengths of tube 34. The tube lengths are equal and each contains porous damper material 36. Each tube length 34 includes a valve 38. A further valve 40 is provided in parallel with each transducer 12, 14.

The branch line 24 also contains damper material 36 adjacent the end sensing the pressure P3 and contains a valve 38.

Each transducer 12, 14 has a further valve 40 arranged in a fluid path in parallel with the transducer housing 18.

The valves 38, 40 are used for isolating a zeroing purposes.

At the junction of the line 22 and the branch line 24 there is an acoustic filter 42 which has the effect of dissipating any perturbations which may tend to arise in the lines 22, 24. The damper material 36 contributes to the same effect and in particular dissipates perturbations, if any, arising in the relatively short tube lengths which connect the transducers 12, 14 to the pipe 10.

The filter 42 as shown provides an increase in internal diameter in the paths from the transducers to the third location, P3. The filter therefore is effective in eliminating relatively lower frequency perturbations by reactive action. In addition the inner wall of the cylindrical part 43 of the filter is lined with acoustically absorbent material 45, which is effective in eliminating relatively higher frequency perturbations by dissipative action. In general, the filter 42 is designed to have a suitable characteristic, which may combine reactive and dissipative action or which may depend on only one or other of those effects, depending on the conditions and nature of the application in which the invention is used.

The form of apparatus shown in Figure 3 is particularly suitable for use as part of an orifice flow meter, the signal outputs from the transducers 12, 14 being passed to an instrument (not shown) calibrated in units of gas flow rate.

As in Figure 2, the paths between the transducers 12, 14 and the branch line 24 through the parts of the line 22 and through parts of the filter 42 are acoustically equivalent so that the upper sides of the transducer elements 16 communicate with the P3 location through respective acoustically equivalent paths, the path through the branch line 24 being a common path, as before.

The apparatus described with reference to Figure 3 of the drawings has particular application, for example, to bulk flow measurement, whether of total flow or flow rate, of natural gas or other compressible fluids where a cost can be attributed to measurement errors. For example, the invention is also applicable to monitoring or measuring flow in gases other than natural gas and in steam or mixtures of steam and water or other mixtures of gases and liquids. The apparatus provides good immunity from in-pipe noise over a wide range of frequencies.

In other applications of the invention (not shown) component in the pipe 10 is a constriction such as a Ventun throat, or an annular orifice or an eccentric orifice for example. Although the location at which P3 is

sensed is, as shown, conveniently immediately downstream of the feature or component such as the plate 30, the location can be chosen to be elsewhere in the pipe, for example upstream of the feature or component, or wherever it is convenient or suitable. The pressure P3 can, in some applications of the invention, be sensed at a location outside the pipe. For example, the pressure of compressible fluid, such as gas, in a vessel to which the line 24 is connected can be sensed as P3.

In other applications of the invention (not shown) the locations at which the P1 and P2 pressures are sensed are upstream and downstream of a feature of the pipe such as a bend, for example, or are on the feature; alternatively, those locations are upstream and downstream of a straight part of the pipe.

CLAIMS

1. Apparatus for monitoring or measuring difference between pressures in compressible fluid at first and second locations comprising first and second differential transducers having respective transducer elements positioned at or adjacent the first and second locations, respectively, respective first sides of the elements communicating with the respective locations and respective second sides of the elements communicating with a common third location through respective acoustically equivalent paths.

2. Apparatus according to claim 1, in which the transducer elements are mounted at openings in wall portions confining the respective first and second locations.

3. Apparatus according to claim 1, in which the transducers have respective pressure ports through which the respective first sides of the transducer elements communicate with the respective first and second locations.

'4. Apparatus according to any preceding claim, in which the second sides of the elements communicate with each other through hollow means which includes a branch leading to the third location.

5. Apparatus according to any preceding claim, in which there is an acoustic filter or damper in the hollow means.

6. Apparatus according to claim 5, in which the filter is a reactive or a dissipative filter or is a filter having both reactive and dissipative characteristics.

7. Apparatus according to any preceding claim, in which at the third location the pressure is intermediate the pressures at the first and second locations.

8. Apparatus according to any preceding claim, in which at least the first and second locations are in a common fluid enclosure.

9. Apparatus according to claim 8, in which all three locations are in a common fluid enclosure.

10. Apparatus according to claim 8, in which the third location is in an enclosure separate from the enclosure in which the first and second locations are situated.

11. Apparatus according to any preceding claim, in which the first and second locations are, respectively, upstream and downstream of a component in a flow pipe or of a feature or part of a flow pipe, or the first and second locations are in the feature or part.

12. Apparatus according to claim 11, in which the component is a restriction in the pipe and in which the third location is downstream of the restriction and upstream of the second location.

13. Apparatus according to claim 11, in which the feature is a bend.

14. Apparatus according to claim 1, substantially as hereinbefore described with reference to Figure 2 of the accompanying drawings.

15. Apparatus according to claim 1, substantially as hereinbefore described with reference to Figure 3 of the accompanying drawings.

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